Mixing and CP Violation in Decays of Charm Mesons

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The phenomenon of mixing in neutral meson systems has now been observed in all flavours, but only in the past year in the D^0 system. The standard model anticipated that, for the charm sector, the mixing rate would be small, and also that *CP* violation, either in mixing or in direct decay, would be below the present levels of observability. It is hoped that further study of these phenomena might reveal signs of new physics. A review of recently available, experimental results is given.

1. INTRODUCTION

Mixing and CP violation (CPV) in the neutral D system were first discussed over thirty years ago [1] but mixing was observed for the first time only very recently [2, 3]. Since then, these observations have been confirmed [4–7] in other experiments and in other D^0 decay modes.

Unlike the K, B and B_s systems, for which mixing was observed years earlier, the short distance ($\Delta C = 2$) amplitude contributing to mixing in the D system arises from box diagrams with down- rather than up-type quarks in the loops. The d and s components are GIM-suppressed, and the b component is suppressed by the small V_{ub} CKM coupling. In the standard model (SM), therefore, long range, non-perturbative effects, a coherent sum over intermediate states accessible to both D^0 and $\overline{D^0}$, are the main contribution to mixing. These are hard to compute reliably, however [8–11].

1.1. Notation and Formalism

D^0 and $\overline{D^0}$ mesons are produced in flavour eigenstates, but propagate in time t and decay as mixtures of eigenstates D_1 and D_2, with masses and widths $M_{1,2}$ and $\Gamma_{1,2}$, related to the flavour states by:

$$|D_1\rangle = p|D^0\rangle + q|\overline{D^0}\rangle \qquad ; \quad |D_2\rangle = p|D^0\rangle - q|\overline{D^0}\rangle \tag{1}$$

It is usual to define mixing parameters x, y, r_M and ϕ_M and a decay parameter λ_f:

$$x = \frac{M_1 - M_2}{\Gamma} \quad ; \quad y = \frac{\Gamma_1 - \Gamma_2}{2\Gamma} \quad ; \quad r_M = \left|\frac{q}{m}\right| \quad ; \quad \phi_M = \mathrm{Arg}\left\{\frac{q}{p}\right\} \quad ; \quad \lambda_f = \frac{q\bar{\mathcal{A}}_f}{p\mathcal{A}_f} \propto e^{i(\delta_f + \phi_f)} \tag{2}$$

in which M and Γ are averages for the two mass eigenstates and δ_f, ϕ_f are strong and weak relative phases, respectively, for the amplitudes $\mathcal{A}_f(\bar{\mathcal{A}}_f)$ for the decays of $D^0(\overline{D^0})$ to the final state f. In the absence of *CPV* in mixing $p = q = 1/\sqrt{2}$ and ϕ_M (the mixing phase) is zero, D_1 is *CP*-even and D_2 is *CP*-odd. If there is no direct *CPV* in decay, then either ϕ_f or $\delta_f = 0$.

Recent estimates for $|x| \sim 1\%$, $|y| \sim 1\%$ are in good agreement with the present observations and are orders of magnitude smaller than values measured for the other neutral mesons. Since charm decays are dominated by the 2×2 sector of the CKM matrix, where weak phases are absent, CPV, in either mixing, or in time-integrated decay rates, is unexpected. Either a large value for $|x|$ (e.g. $> |y|$) or the observation, at current sensitivities, of *CPV* in charm decays would be regarded as an indication of new physics [9–12].

In the following section, we discuss the experimental evidence for mixing as observed in time-dependent effects in hadronic decays. Then, in section 2.2 we present results from its effect on lifetimes. In section 4, we outline the

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*From the *BABAR* collaboration.

present state of experimental searches forCPV in time-integrated decay rates of charmed mesons in section 4. In section 5, we present a summary of the current knowledge on mixing parameters and outline possibilities for future progress.

2. EVIDENCE FOR MIXING IN TIME-DEPENDENCE OF DECAYS

It follows from Eqs. (1) and (2) that mixing gives rise to a time-dependence in amplitudes $\mathcal{A}(\bar{\mathcal{A}})_{f(\bar{f})}$ for decays $D^0(\overline{D^0}) \rightarrow f(\bar{f})$. When the final state f is accessible to decay by both D^0 and $\overline{D^0}$, interference between direct decay and decay preceded by mixing will occur. Neglecting CPV and terms in x or y beyond second order, the decay rate for $D^0 \rightarrow \bar{f}$, for example, deviates from exponential

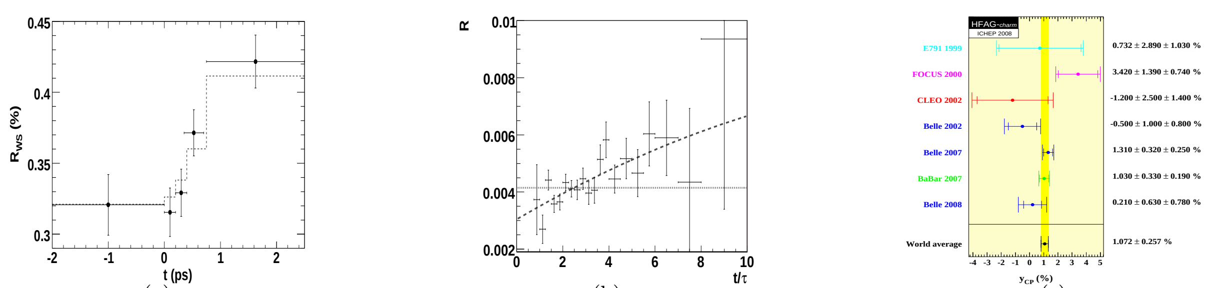
$$|\mathcal{A}_{\bar{f}}(t)|^2 = e^{-\Gamma t} \times \left[|\mathcal{A}_{\bar{f}}|^2 + (y \cos\delta_f - x \sin\delta_f)\, |\mathcal{A}_{\bar{f}}||\bar{\mathcal{A}}_{\bar{f}}|(\Gamma t) + \frac{(x^2+y^2)}{4} |\bar{\mathcal{A}}_{\bar{f}}|^2 (\Gamma t)^2 \right]. \qquad (3)$$

The first term in square parentheses is the direct decay rate, the third is proportional to the mixing rate $(x^2+y^2)/2$ and the middle term comes from the interference. The latter makes it possible to measure the small quantities x and y to first order, but only if the strong phase difference δ_f is known.

2.1. Evidence for Mixing In $\mathrm{D}^0 \rightarrow \mathrm{K}^+\pi^-$ Decays

Observation of the deviations from exponential in the "wrong-sign" (WS) decays $D^0 \rightarrow K^+\pi^-$ [1], a signal for $D^0 - \overline{D^0}$ mixing, has been attempted many times [13–18] without success. These very rare decays are Doubly-Cabibbo-suppressed (DCS) and must be compared, experimentally, with the far more copious, "right-sign" (RS) Cabibbo-Favoured (CF) decays to $K^-\pi^+$, in which the deviations are negligibly small.

The *BABAR* collaboration, using a huge $384 fb^{-1}$ e^+e^- sample of D^0 mesons, whose flavour was determined from the sign of the pion from the $D^{*+} \rightarrow D^0\pi^+$ decays from which they came, were finally able to observe mixing. In Fig. 1(a), the ratio of WS to RS decays of the combined sample of D^0 and $\overline{D^0}$ decays is shown as a function of proper time t. The average value of this ratio, $\sim 0.36\%$, is clearly not constant. The mixing fit, including a linear rise corresponding to the second term in Eq. (3), is preferred.



(a) (b) (c)

Figure 1: Evidence for $D^0 - \overline{D^0}$ mixing. The ratio of WS/RS yields as a function of proper time t is shown for the (a) *BABAR* and (b) CDF experiments. The dashed plot in (a) shows the projection of the mixing fit onto the time axis, and has a χ^2 of 1.5. The flat line (no mixing fit) has χ^2 of 24. The dashed line in (b) is a parabolic fit giving values for the DCS rate, x'^2 and y'. In (c), the Heavy Flavour Averaging Group (HFAG) [19] summary of measurements of y_{CP} is presented. The mean, $1.072 \pm 0.257\%$, differs significantly from the no-mixing expectation of zero.

[1]Hereafter, unless otherwise stated, it is implied that charge conjugate modes are included.

The strong phase $\delta_{K\pi}$ was poorly known, so this measurement was only able to determine values for $y' = (9.7 \pm 4.4 \pm 3.1) \times 10^{-3}$, $x'^2 = (-0.22 \pm 0.30 \pm 0.21) \times 10^{-3}$ and $R_D = (0.303 \pm 0.019)\%$, where

$$x' = x \cos \delta_{K\pi} + y \sin \delta_{K\pi} \quad ; \quad y' = y \cos \delta_{K\pi} - x \sin \delta_{K\pi}$$

and R_D is the ratio of DCS ro CF decay rates. The *BABAR* result was found to be inconsistent with a no mixing hypothesis, with a significance estimated at 3.9σ. These results assumed no CPV. Separate fits to D^0 and to $\overline{D^0}$ showed no significant difference. It was concluded that no CPV was observable at the current precision.

Using a similar technique, but with data from 1.96 TeV $p\bar{p}$ collisions, the CDF experiment has confirmed this result with a 3.8σ significance [5]. The plot of WS/RS ratio vs. t is shown in Fig. 1(b). Assuming no CPV, they obtained values $x'^2 = (-0.12 \pm 0.35) \times 10^{-3}$, $y' = (8.5 \pm 7.6) \times 10^{-3}$ and $R_D = (0.304 \pm 0.055)\%$, in excellent agreement with those from *BABAR*.

2.2. Lifetimes for Decays to CP-even Final States

Deviations from exponential decay, introduced by mixing, alters the effective lifetimes τ for D^0 decays in ways that depend upon the *CP* symmetry of the final state [20, 21]. Decays to $K^-\pi^+$ (mixed *CP*) and to K^-K^+ or $\pi^-\pi^+$ (*CP*-even) have been used in searches for mixing by measuring the quantities

$$y_{CP} = \frac{\tau(D^0 \to K^-\pi^+)}{\tau(D^0 \to h^-h^+)} - 1 \quad ; \quad A_\tau = 2\tau_{K^-\pi^+} \left(\frac{\tau^+_{hh} - \tau^-_{hh}}{\tau^+_{hh} + \tau^-_{hh}} \right) \tag{4}$$

Both are zero in the absence of mixing or CPV. Clear evidence for mixing ($y_{CP} \neq 0$) has now been seen in this way by both the Belle [3] and *BABAR* [4] collaborations with significances of 3.2σ and 3.0σ, respectively These results, with those of earlier, unsuccessful searches for mixing, are summarized in Fig. 1.

No evidence for CPV ($A_\tau \neq 0$) is yet observed, however. Belle measured $A_\tau = (0.010 \pm 0.300 \pm 0.150)\%$ and *BABAR* obtained [2] $A_\tau = (0.260 \pm 0.360 \pm 0.080)\%$ giving an average $A_\tau = (0.123 \pm 0.248)\%$.

2.3. Mixing in $\mathrm{D}^0 \to \mathrm{K}^+\pi^-\pi^0$ Decays

The *BABAR* experiment has just reported further evidence for mixing in WS D^0 decays to $K^+\pi^-\pi^0$. [7]. For this three-body channel, each decay is represented as a point in a Dalitz plot, defined by the squared invariant masses (s_0, s_+) of the $K^+\pi^-$ and $K^+\pi^0$ systems, respectively. The final state f and the value for the strong phase $\delta_f = \delta_{K\pi\pi} + \mathrm{Arg}\left(\bar{\mathcal{A}}_{\bar{f}} / \mathcal{A}_{\bar{f}}\right)$ in Eq. (3) is then unique at each such point. The CF and DCS decay amplitudes $\bar{\mathcal{A}}_{\bar{f}}$ and $\mathcal{A}_{\bar{f}}$, respectively, can be determined from fits to their Dalitz plot densities, but the constant phase $\delta_{K\pi\pi}$ cannot.

The *BABAR* collaboration identified a sample of $\sim 3,000$ WS and $\sim 660,000$ RS $D^0 \to K\pi\pi^0$ events in a tight signal region with flavours identified by their origin from D^{*+} decays. The RS sample was very clean, though the WS sample had a 50% background, mostly from "mis-tagged" RS decays.

An isobar model for the amplitude $\bar{\mathcal{A}}_{\bar{f}}$ was determined from a time-integrated fit to the distribution of events on the RS (mostly CF) Dalitz plot. A second, time-dependent fit to the WS Dalitz plot then determined parameters for the DCS amplitude $\mathcal{A}_{\bar{f}}$ and x'', y'' (x and y rotated by the unknown phase $\delta_{K\pi\pi}$) summarized in Table I.

Table I: Mixing parameters $x'' = x \cos \delta_{K\pi\pi} + y \sin \delta_{K\pi\pi}$ and $y'' = y \cos \delta_{K\pi\pi} - x \sin \delta_{K\pi\pi}$ from the *BABAR* analysis of $D^0 \to K^+\pi^-\pi^0$ decays. These are related to x and y by an undetermined strong phase rotation $\delta_{K\pi\pi}$.

[2] *BABAR* measured the asymmetry in $\Delta Y = (y^+_{CP} - y^-_{CP})/(y^+_{CP} + y^-_{CP}) \approx 2\tau^0 A_\tau/(\tau^+ + \tau^-)$.

Sample	$\mathbf{x''}$	$\mathbf{y''}$
$\mathbf{D^0}$ and $\mathbf{\overline{D^0}}$	$[\ 2.61^{+0.57}_{-0.68}(\text{stat.}) \pm 0.39(\text{syst.})]\%$	$[-0.06^{+0.55}_{-0.64}(\text{stat.}) \pm 0.34(\text{syst.})]\%$
$\mathbf{D^0}$ only	$[\ 2.53^{+0.54}_{-0.63}(\text{stat.}) \pm 0.39(\text{syst.})]\%$	$[-0.05^{+0.63}_{-0.67}(\text{stat.}) \pm 0.50(\text{syst.})]\%$
$\mathbf{\overline{D^0}}$ only	$[\ 3.55^{+0.73}_{-0.83}(\text{stat.}) \pm 0.65(\text{syst.})]\%$	$[-0.54^{+0.40}_{-1.16}(\text{stat.}) \pm 0.41(\text{syst.})]\%$

The significance of the mixing signal in the fit to the combined D^0 and $\overline{D^0}$ samples, ignoring CPV, was 3.2σ. Separate fits to each sample show no evidence for CPV.

3. OTHER MIXING MEASUREMENTS

Two other channels have recently been analyzed in which the mixing signal was of less significance, but where mixing parameters were, nevertheless, measurable.

3.1. $\mathbf{D^0 \to K_S\pi^-\pi^+}$ Decays

Analysis of this channel, pioneered by the CLEO collaboration [22] is of great interest due to the presence of CP-eigenstates in the final state. These tie the phase of the amplitudes for D^0 and $\overline{D^0}$ decay amplitudes together, so that $\delta_{K\pi\pi}$ in Eq. (**??**) is zero. Thus, measurements of x, y and the two CPV parameters $|q/p|$ and $\phi_{K_S\pi^-\pi^+}$ can be made free of unknown phases.

CLEO's analysis used a $9 fb^{-1}$ e^+e^- sample and found only an upper limit for mixing parameters $(-4.7 < x < 8.6)\%$ and $(-6.1 < y < 3.5)\%$ at 95% CL. The Belle collaboration has repeated the analysis with a $540 fb^{-1}$ sample (534K events) [4], observing mixing at the 2.4σ significance. The parameter values obtained are summarized in Table II. It is noteworthy that the value for y here is not consistent with the world average value for $y_{CP} = 1.072 \pm 0.275\%$ discussed in section 2.2.

Table II: Mixing parameters obtained from the Belle analysis of $D^0 \to K_S\pi^-\pi^+$ decays. The third error is that due to uncertainties in the model used to define the Dalitz plot amplitudes.

$\mathbf{x}$	$\mathbf{y}$	$\mathbf{|q/p|}$	$\mathrm{Arg}(\mathbf{q/p})$
$(0.80 \pm 0.29^{+0.09+0.10}_{-0.07-0.14})\%$	$(0.33 \pm 0.24^{+0.08+0.06}_{-0.12-0.08})\%$	$0.86^{+0.30+0.06}_{-0.29-0.03} \pm 0.08$	$(-14^{+16+5+2}_{-18-3-4})^\circ$

There was no evidence for CPV since the magnitude of q/p was consistent with unity and its phase was zero.

3.2. CP-odd Final States

A new result from Belle [23]. has examined lifetime differences between the decays to the CP-odd final state $D^0 \to \phi K_S$ with decays to the CP-even background and ϕ sideband regions. A novel method was chosen over a time-dependent analysis of the whole $K_SK^-K^+$ Dalitz plot like that used for the $K_S\pi^-\pi^+$ channel which required a flavour-tagged sample of D^0's from D^* decays. The sample size available was thereby enhanced almost threefold.

Approximately 130K $D^0 \to K^-K^+K_S$ decays were extracted from a $697 fb^{-1}$ sample of e^+e^- collisions, with no attempt to distinguish D^0 from $\overline{D^0}$. Lifetimes τ_A and τ_B were measured, respectively, for events in the K^-K^+ invariant mass regions A (containing the ϕ) and B (narrow sidebands above and below the ϕ where CP-even $a_0(980)K_S$, $f_0(980)K_S$ and non-resonant decays were dominant).

Decay amplitudes $\mathcal{A}_{1,2} = \mathcal{A}(s_0, s_+) \pm \mathcal{A}(s_0, s_-)]/\sqrt{2}$ were obtained from a fit [24, 25] to the distribution of events in the $K^-K^+K_S$ Dalitz plot. Here, s_0, s_- and s_+ were, respectively, K^-K^+, K_SK^- and K_SK^+ squared invariant mass combinations. Neglecting CPV, $|\mathcal{A}_{1,2}|^2$ should have approximately exponential time-dependences with lifetimes $\tau_{1,2} = \tau/(1 \pm y_{CP})$, and their interference $\mathcal{A}_1^*\mathcal{A}_2$ should be zero when integrated over the s_+ coordinate.

A value for y_{CP} was extracted from the difference between (τ_A and τ_B) and the "*CP*-ness", of each region, obtained by integration of these amplitudes.

The result, $y_{CP} = (0.21 \pm 0.63 \pm 0.78 \pm 0.01$, where the third uncertainty accounts for uncertainties in the decay model used to describe the decay amplitude $\mathcal{A}$, was included in Fig. 1(c). This result ranks third in precision for measurements of y_{CP}. It is important that it agrees quite well with all other results from the *CP*-even modes.

4. SEARCHES FOR CPV IN CHARM MESON DECAYS

SM expectations for *CP* asymmetries in time-integrated decays in the charm sector are small. Singly-Cabibbo-Suppressed (SCS) decays are of particular interest since these allow for asymmetries, at the $\sim 0.1\%$ level, from gluonic penguins [12, 26–28]. Observation of CPV at current sensitivities would be an indication for new physics.

The asymmetry is defined as

$$A^f_{CP} = \frac{\Gamma(D \to f) - \Gamma(\bar{D} \to \bar{f})}{\Gamma(D \to f) + \Gamma(\bar{D} \to \bar{f})}$$

For D^0 asymmetries, there could be contributions from both direct CPV and from mixing. The latter is small since $A_\tau \sim 0.1\%$.

Experimentally, measurement of asymmetries at the 10^{-3} level are limited by uncertainties in asymmetries in the detection and reconstruction of particles of opposite charge. Also, for D^0 decays, efficiencies for D^{*+} tagging cannot be assumed to be the same as that for D^{*-}. Forward-backward production asymmetries, resulting from Z^0/γ interference and higher order loops in the production of $c\bar{c}$ quarks, results in asymmetries in the distribution of D decay products in regions of varying efficiency in the detector.

Calibration of these factors used to rely upon Monte Carlo simulated event (MC) studies, with questionable assumptions about charge-dependent interaction effects, resulting in systematic uncertainties in A_{CP}'s in the $1 - 5\%$ range. In the past year, new insights in using data rather than MC have led to reduction of these uncertainties to the $0.2 - 0.4\%$ range [29].

Large samples of CF $D^0 \to K^-\pi^+$ decays, selected from the *BABAR* $386 fb^{-1}$ data sample, were used to provide information on the efficiency asymmetries in small momentum and angular range. The underlying assumption was that the integrated production rates for D^0 and $\overline{D^0}$ were the same. Forward-backward production asymmetries were dealt with by measuring event yields in forward and backward separately.

Asymmetries obtained in this way, are summarized in Table III. Other, recent measurements are also included.

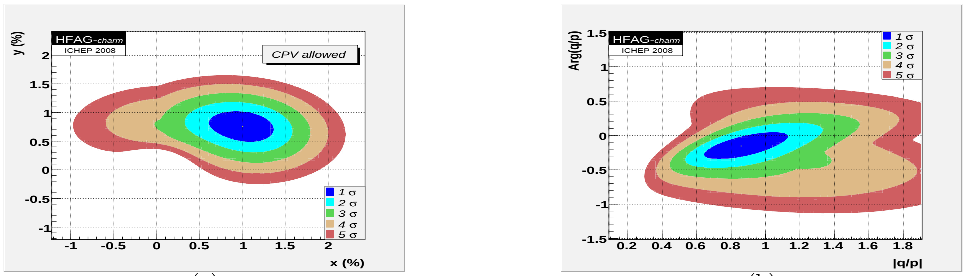
Table III: Recent measurements of *CP* decay asymmetries $\times 10^{-2}$. The first uncertainty is statistical, the second is systematic. Data were used to estimate asymmetries in efficiency in all but ref. [30].

Mode	***BABAR*** $\times 10^{-2}$	**Belle** $\times 10^{-2}$	**CLEO** $\times 10^{-2}$
$\mathbf{D^0} \to \mathbf{K^-K^+}$	$0.00 \pm 0.34 \pm 0.13$ [29]	$-0.43 \pm 0.30 \pm 0.11$ [31]	—
$\mathbf{D^0} \to \pi^-\pi^+$	$-0.24 \pm 0.52 \pm 0.22$ [29]	$0.43 \pm 0.52 \pm 0.12$ [31]	—
$\mathbf{D^0} \to \mathbf{K^-K^+}\pi^\mathbf{0}$	$1.00 \pm 1.67 \pm 0.25$ [32]	—	—
$\mathbf{D^0} \to \pi^-\pi^+\pi^\mathbf{0}$	$-0.31 \pm 0.41 \pm 0.17$ [32]	$-0.43 \pm 0.41 \pm 1.23$ [30]	—
$\mathbf{D^+} \to \mathbf{K^-K^+}\pi^+$	—	—	$-0.03 \pm 0.84 \pm 0.29$ [33]

These asymmetries are consistent with zero, with most systematic uncertainties much less than 1%. Of particular interest is the observation that both statistical and systematic uncertainties should scale with the square root of the number of events. Future measurements from flavour factories may well detect asymmetries at or above the SM limit.

5. SUMMARY

The Heavy Flavour Averaging Group (HFAG) has combined a wide range of mixing observables (28 in all) including all those discussed here. To do this, they made a χ^2 fit [34] to obtain values for the underlying mixing parameters (x, y, $|q/p|$,*etc.*) that best described these. The results are best summarized in the χ^2 countour plots in Fig. 2 for the fit that allowed for *CPV*. The combined evidence for mixing is now compelling. The probability for $x = y = 0$



(a) (b)

Figure 2: χ^2 contours for fit to mixing observables. (a) x vs. y and (b) $|q/p|$vs. Arg(q/p). This figure is taken from the Heavy Flavour Averaging Group (HFAG) [19]

(no mixing) is excluded from a fit with no *CPV* at the 9.8σ level. The present data are also consistent with the absence of *CPV*. No evidence for *CPV* in time-integrated decay rates for neutral D mesons exists either, though the measurements are approaching the interesting level of sensitivity that could confront SM estimates. Furthermore, systematic as well as statistical uncertainties are expected to shrink as more data at present and future flavour factories is accrued.

We should take this as a need to continue to press on with these studies in case there is yet a hole in the SM at the energy scale that can be probed with results from a flavour factory.

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References

[1] A. Pais and S. B. Treiman. *CP* Violation in Charmed Particle Decays. *Phys. Rev.*, D12:2744–2750, 1975.
[2] B. Aubert et al. Evidence for D^0-$\overline{D^0}$ mixing. *Phys. Rev. Lett.*, 98:211802, 2007.
[3] M. Staric et al. Evidence for D^0-$\overline{D^0}$ Mixing. *Phys. Rev. Lett.*, 98:211803, 2007.
[4] K. Abe et al. Measurement of D^0-$\overline{D^0}$Mixing in $D^0 \to K_S\pi^+\pi^-$ Decays. *Phys. Rev. Lett.*, 99:131803, 2007.
[5] T. Aaltonen. Evidence for D^0-$\overline{D^0}$ Mixing Using the CDF II Detector. arXiv:0712.1567 [hep-ex], 2007.
[6] B. Aubert et al. Measurement of $D^0 - \overline{D^0}$ Mixing using the Ratio of Lifetimes for the Decays $D^0 \to K^-\pi^+$, K^-K^+ and $\pi^-\pi^+$. *Phys. Rev.*, D78:011105, 2008.
[7] B. Aubert et al. Measurement of D^0-$\overline{D^0}$ Mixing from a Time-dependent Amplitude Analysis of $D^0 \to K^+\pi^-\pi^0$ Decays. arXiv:0807.4544 [hep-ex], 2008.
[8] Lincoln Wolfenstein. $D^0 - \overline{D^0}$ Mixing. *Phys. Lett.*, B164:170, 1985.
[9] Ikaros I. Y. Bigi and Nikolai G. Uraltsev. $D^0 - \overline{D^0}$ Oscillations as a Probe of Quark-hadron Duality. *Nucl. Phys.*, B592:92–106, 2001.

[10] Eugene Golowich, JoAnne Hewett, Sandip Pakvasa, and Alexey A. Petrov. Implications of $D^0-\overline{D^0}$ Mixing for New Physics. *Phys. Rev.*, D76:095009, 2007.

[11] Eugene Golowich, Sandip Pakvasa, and Alexey A. Petrov. New physics contributions to the Lifetime Difference in $D^0-\overline{D^0}$ Mixing. *Phys. Rev. Lett.*, 98:181801, 2007.

[12] Yuval Grossman, Alexander L. Kagan, and Yosef Nir. New physics and CP violation in Singly Cabibbo Suppressed D decays. *Phys. Rev.*, D75:036008, 2007.

[13] E. M. Aitala et al. A Search for $D^0-\overline{D^0}$ Mixing and Doubly-Cabibbo-Suppressed Decays of the D^0 in Hadronic Final States. *Phys. Rev.*, D57:13–27, 1998.

[14] R. Godang et al. Search for $D^0-\overline{D^0}$ Mixing. *Phys. Rev. Lett.*, 84:5038–5042, 2000.

[15] J. M. Link et al. Measurement of the Doubly Cabibbo Suppressed Decay $D^0 \rightarrow K^+\pi^-$ and a Search for Charm Mixing. *Phys. Lett.*, B618:23–33, 2005.

[16] K. Abe et al. Search for $D^0-\overline{D^0}$ Mixing in $D^0 \rightarrow K^+\pi^-$ Decays and Measurement of the Doubly-Cabibbo-Suppressed Decay Rate. *Phys. Rev. Lett.*, 94:071801, 2005.

[17] B. Aubert et al. Search for $D^0-\overline{D^0}$ Mixing in the Decays $D^0 \rightarrow K^+\pi^-\pi^+\pi^-$. arXiv:hep-ex/0607090, 2006.

[18] L. M. Zhang et al. Improved Constraints on $D^0-\overline{D^0}$ Mixing in $D^0 \rightarrow K^+\pi^-$ Decays at Belle. *Phys. Rev. Lett.*, 96:151801, 2006.

[19] A Schwartz et al. Heavy flavour averaging group. $http://www.slac.stanford.edu/xorg/hfag/charm/ICHEP08/results_{m}ix$ 2008

[20] Tie-hui (Ted) Liu. The $D^0-\overline{D^0}$ Mixing Search: Current Status and Future Prospects. arXiv:hep-ph/9408330, 1994.

[21] Sven Bergmann, Yuval Grossman, Zoltan Ligeti, Yosef Nir, and Alexey A. Petrov. Lessons from CLEO and FOCUS Measurements of $D^0-\overline{D^0}$ Mixing Parameters. *Phys. Lett.*, B486:418–425, 2000.

[22] D. M. Asner et al. Search for $D^0-\overline{D^0}$ Mixing in the Dalitz Plot Analysis of $D^0 \rightarrow K_S\pi^+\pi^-$. *Phys. Rev.*, D72:012001, 2005.

[23] A Zupanc et al. Measurement of y_{CP} in D Meson Decays to *CP* Eigenstates. 2008.

[24] B. Aubert et al. Dalitz Plot Analysis of $D^0 \rightarrow \bar{K}^0K^+K^-$. *Phys. Rev.*, D72:052008, 2005.

[25] B. Aubert et al. Improved Measurement of the CKM Angle Gamma in $B^\mp \rightarrow D^{(*)0}K^{(*)\mp}$ Decays with a Dalitz Plot Analysis of D Decays to $K_S\pi^+\pi^-$ and $K_SK^+K^-$. *Phys. Rev.*, D78:034023, 2008.

[26] F. Buccella, Maurizio Lusignoli, G. Miele, A. Pugliese, and Pietro Santorelli. Nonleptonic Weak Decays of Charmed Mesons. *Phys. Rev.*, D51:3478–3486, 1995.

[27] S. Bianco, F. L. Fabbri, D. Benson, and I. Bigi. A Cicerone for the Physics of Charm. *Riv. Nuovo Cim.*, 26N7:1–200, 2003.

[28] Alexey A. Petrov. Hunting for *CP* Violation with Untagged Charm Decays. *Phys. Rev.*, D69:111901, 2004.

[29] B. Aubert et al. Search for *CP* Violation in the Decays $D^0 \rightarrow K^-K^+$ and $D^0 \rightarrow \pi^-\pi^+$. *Phys. Rev. Lett.*, 100:061803, 2008.

[30] K. Arinstein. Measurement of the Ratio $B(D^0 \rightarrow \pi^+\pi^-\pi^0)/B(D^0 \rightarrow K^-\pi^+\pi^0)$ and the Time-integrated CP Asymmetry in $D^0 \rightarrow \pi^+\pi^-\pi^0$. *Phys. Lett.*, B662:102–110, 2008.

[31] M. Staric et al. Measurement of CP Asymmetry in Cabibbo Suppressed D^0 Decays. arXiv:0807.0148, 2008.

[32] B. Aubert et al. Search for *CP* Violation in Neutral D Meson Cabibbo-Suppressed Three-body Decays. *Phys. Rev.*, D78:051102, 2008.

[33] P. Rubin et al. Search for *CP* Violation in the Dalitz-Plot Analysis of $D^\pm \rightarrow K^+K^-\pi^\pm$. *Phys. Rev.*, D78:072003, 2008.

[34] A. J. Schwartz. Measurements of $D^0\overline{D^0}$ Mixing and Searches for *CP* Violation: HFAG Combination of All Data. arXiv:0803.0082, 2008.